an Industrial Waste Guide to the

Cane Sugar Industry

Prepared through cooperation of the American Sugar Cane League and the National Technical Task Committee on Industrial Wastes

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service | Bureau of State Services

Division of Water Supply and Pollution Control

Foreword

In the Cane Sugar Industry, as in many other industries, control and disposal of wastes is of major concern. There are two important reasons for increased attention to these problems: First, the greatest possible recovery, use, and reduction of wastes is necessary for most economical production in small as well as in large plants. Second, protecting the Nation's limited water resources for maximum use is essential to our health and continued economic growth. Stream pollution control is mutually beneficial to industry, the individual citizen, and the Nation as a whole. Thus, wastes which cannot be eliminated must be disposed of in a manner which will not impair the usefulness of stream waters for other beneficial purposes.

This "Industrial Waste Guide to the Cane Sugar Industry" is intended primarily to assist the operators and managers of cane sugar factories to utilize, reduce, and otherwise suitably dispose of waste waters. It will be useful in informing consultants and personnel of regulatory agencies of the source and characteristics of process wastes and current practices for their treatment and disposal in controlling water pollution. The guide was prepared for the Cane Sugar Industry by Arthur G. Keller, Professor of Chemical Engineering, Louisiana State University, serving as a representative of the American Sugar Cane League on the National Technical Task Committee on Industrial Wastes. It was submitted for publication to the Public Health Service through the Task Committee.

The National Technical Task Committee on Industrial Wastes is composed of representatives from the Nation's leading industries concerned with solving difficult industrial waste problems. The objective of the organization is to perform technical tasks pertaining to industrial wastes in cooperation with the Public Health Service and all others concerned with improving the quality of our water resources. The preparation of this guide was one of the tasks assumed by the Cane Sugar Industry in carrying out this objective.

This is the sixth of a series of Industrial Waste Guides prepared by the National Technical Task Committee in cooperation with the Public Health Service.

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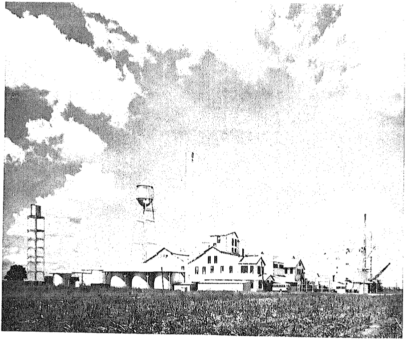


A cane sugar factory

an Industrial Waste Guide to the

CANE SUGAR INDUSTRY

Introduction

The Cane Sugar Industry is characterized by a relatively large number of plants located in predominantly rural areas. With the rapid industrialization of many of these areas and the increased interest in public water bodies, the industry in many areas has given study to its operations with a view to minimizing the pollutional load from its plants.

Published information on the water usage of cane sugar factories and on their waste loads is rather limited and concerned mainly with conditions in Louisiana where pollution from this source has long been a problem. The Stream Control Commission of Louisiana at Baton Rouge has an excellent collection of data on the variations in waste loads. The publications listed in the bibliography also provide useful information.

This guide summarizes available information on the nature, types, and amounts of wastes produced by the industry, and the methods which have been developed and used to overcome or minimize the harmful effects of waste effluents.

Magnitude of the Problem

Cane sugar is produced in the continental United States in Louisiana and Florida. The industry in Louisiana is located in 20 of the south central parishes (counties) of the State, in a flat area which is traversed by a large number of relatively slow-moving streams or bayous. There are 48 operating factories in the area. Operations are seasonal and normally extend from October 15 through January 1. In Florida, the production of sugar is concentrated in the area of the Everglades to the north and west of Miami. There are two large factories in this area. A third factory is located some 150 miles north of Miami in an area which is somewhat similar to the Glades, but with a more sandy type subsoil. The three Florida factories produce about one-fourth of the total production of cane sugar in the continental United States.

In Puerto Rico there are concentrated some 30 sugar factories which produce about 1 million tons of sugar each year. In view of the relatively small size of the island, about 3,500 square miles, the factory density is relatively high. A similar situation prevails in the other major domestic sugar-producing area, Hawaii.

There are about the same number of sugar factories in Hawaii as in Puerto Rico. Factories are scattered over four of the principal islands and are producing roughly 1 million tons of sugar a year. In this area, unlike the other areas mentioned, production is continuous throughout the year.

Cane sugar is produced throughout the world, generally in a belt extending from about 30° north of the Equator to an equal distance south of the Equator. World production of cane sugar is about 27 million metric tons annually. This production is reported from a total of some 56 countries.

A complete listing of all the sugar factories in the world has never been compiled, but from a number of estimates which have been prepared it would appear that there are some 3,000 factories producing centrifugal or crystalline type sugar, plus an equal number which are producing sugar concrete. Factories vary widely in size and efficiency.

In some areas of the Far East, for example, factories producing sugar concrete may process as little as one ton of sugar cane per day and a total of not over 100 tons of sugar cane per year. From this we go to the other extreme where factories in the West Indies and Mexico process as much as 20,000 tons of sugar cane per day and 2 to 3 million tons of sugar cane per year. The average factory of economic size in the Western

Hemisphere has a capacity of about 2,000 tons of cane per day and 25,000 tons of sugar per season.

On a worldwide basis, the sugar obtained from a ton of cane averages about 10 percent by weight of the cane. Yields fluctuate from a minimum of 6 percent in the poorest areas with the least efficient mills to as much as 15 percent in certain areas which have very efficient mills in combination with excellent cane.

Every sugar factory uses large amounts of water in connection with its operations. The washings from these factories contain considerable amounts of sugars which have a very high B.O.D. value. Under normal conditions about 3 to 4 percent by weight of the cane is discharged from the process in the form of a filter cake which may, under certain conditions, be a pollution hazard. In the more primitive type factory, considerable amounts of sugar-bearing materials are discharged to local watercourses and serious pollution frequently results from such action. The pollution load from sugar factories has been considerably increased in recent years as a result of the mechanization of cane-harvesting operations in many of the domestic sugar-producing areas and in some other areas, notably Australia.

Description of Process

The raw material for the sugar-manufacturing operation is sugar cane. Since many of the waste disposal problems arise because of the condition of the cane delivered to the factories, it will be well to mention briefly something about this raw material.

The sugar cane ordinarily averages about 15 percent by weight of fiber and about 85 percent by weight of water and soluble solids. The cane, as grown, is a type of giant grass and is a perennial. For many years it was the practice to harvest the sugar cane by cutting the stalk free from the soil with a knife or machete, stripping off the adhering leaves, and removing the topmost joints which contain little or no sugar. In this operation there remain two cut ends on each stalk of cane from which limited amounts of sugar-bearing juices exude. Because of the shortage of labor in many of the domestic areas, this method of harvesting cane has been abandoned in favor of mechanical harvesting and loading machines as shown in Figures 1 and 2.

In the mechanical harvesting operation as practiced in Louisiana, machines enter the field of cane, cut it free from the ground with revolving knives and remove the top with another revolving blade. In the process the cane is held in chains which are provided with sticker bars to keep the material from falling free when cut. Such cane is usually damaged at several points because of the action of the sticker bars and the mechanical handling in the harvesting operation. The

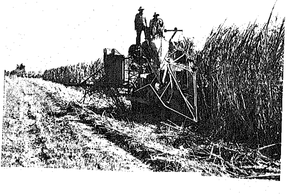
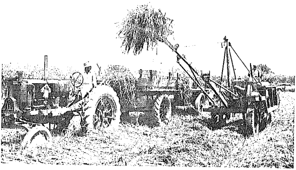


Figure 1.—Sugar cane harvesting with mechanical equipment.

Figure 2.—Loading cane for transportation to sugar factory.



harvested cane is subsequently burned to remove adherent trash and is mechanically loaded into carts or wagons for transfer to the sugar factory.

The amount of trash included in cane deliveries varies widely. For cane which has been manually harvested and loaded the amount of extraneous material does not ordinarily exceed 5 percent. With mechanical harvesting the total extraneous material may vary from a minimum of 5 percent to a maximum of 50 percent of the weight of the cane delivered. In Louisiana the amount of extraneous material seldom exceeds 20 percent by weight of the deliveries, but in Hawaii where harvesting methods are more drastic, the higher figure is frequently achieved, especially during periods of inclement weather. The cane-washing plants which will be discussed later are intended primarily for the removal of the large amounts of soil which are included in the cane deliveries. These frequently are as much as 50 percent of the total amount of extraneous material present.

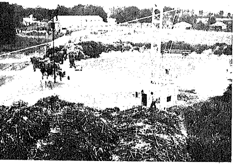


Figure 3.—Cane is mechanically removed from vehicles on arrival at the sugar factory.

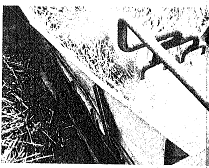


Figure 4.—Cleaning cane is first step in processing, with the use of large amounts of fresh water.

The Process

Upon receipt at the sugar factory the cane is weighed and is either sent directly to the process or stored for short periods of time either in the original vehicle in which it was received or in piles in the yard area of the sugar factory. The cane is usually handled with large derricks equipped with mechanical grabs or it may be handled in chain slings. (See Figure 3.) In either case, considerable damage to the stalks of cane results from the mechanical handling operation.

Where the major portion of the cane delivered to a factory has been manually harvested and loaded, the cane goes directly from the unloading or storage area to the milling plant. Where mechanical harvesting is practiced, the majority of the factories have installed cane laundries or cleaning plants in an attempt to remove at least a portion of the extraneous material. These cleaning plants vary from a simple spray arrangement over the conveyor moving the cane into the factory, such as shown in Figure 4, representing an investment of about $5,000, to elaborate laundries representing an investment of approximately $1 million, such as are found in a number of factories in Hawaii.

In these laundries the cane is spread out in as thin a layer as the physical arrangement of the conveying equipment will permit and is washed with large volumes of water. The water which has been used for condensing vapors in the barometric condensers is frequently employed for washing cane. This is in the interest of economy in use of water and also to take advantage of the heat present in the waste water from the condensers. The total amounts used vary from one-half million to as much as 4 million gallons per 24-hour day, depending upon the size of the factory, the availability of water, and particularly, the means available for the disposal of the water after the washing operation.

After the washing operation the cane is passed through preparatory equipment to reduce its bulk volume and subsequently through a series of three roller mills where it is subjected to a crushing and grinding operation to remove as great a percentage of the sucrose present as is economically possible. (See Figures 5 and 6.) To aid in the operation, the partially crushed cane is wetted with water in the latter stages of the crushing operation. This operation is known as maceration. Juices squeezed out by the last mills in the train are recycled and used to wet cane in the early stages of the crushing operation to obtain more effective use of the water which has been applied. The extracted juices are screened to remove coarse particles of cane or bagasse and are then sent to process.

The material removed by screening is returned to the milling plant. The residue from the milling operation, which is the fibrous portion of the cane, is called bagasse. This will normally amount to about 30 per-

Figure 5.—Cleaned cane is reduced in bulk by knifing as it is conveyed to the milling process.

cent by weight of the cane entering the operation. It averages about 48 percent moisture and is employed in the great majority of factories as a low-grade fuel.

The bagasse from the milling operation goes to the boiler plant where it is used to generate steam required in the operation of the factory. Under normal conditions, a well-designed factory can be operated on the steam produced from the bagasse resulting from the milling operation. The boiler plant operates on fresh water at the beginning of the grinding operations but, subsequently, is able to make use of the condensate from the processing operation in place of fresh water. In most plants the amount of condensate produced by the evaporation of the cane juice and the condensation of steam from all engines, turbines, and other such prime movers is normally more than sufficient to supply boiler needs. The excess condensate is used at various places in the process. Any condensate over and above boiler needs is discarded.

Steam generated by the boilers is used to operate the milling plant and the turbogenerator units which furnish electricity to operate the balance of the factory. The exhaust from the prime movers is used as the process steam in the operation. Any deficiency in exhaust steam is made up by an automatic pressure-regulating valve which communicates the live steam and exhaust steam mains of the plant.

The dilute juice extracted by the milling operation is sent to process. Here, after weighing or measuring, it is treated with a slurry of calcium hydroxide to raise the pH value of the cold juice to about 8–8.5. Following this operation it is passed through heat exchangers where the temperature is raised to about 215° F. The heated juice is passed to a continuous sedimentation unit where it is separated into two portions. The clarified or clear juice continues in process, while the underflow or "muds" is sent to a rotary vacuum filter. The filter cake from this operation is discarded, and the filtrate is recycled to the entering dilute juice stream. The filter cake from the factory may be removed in the dry form or it may be slurried and pumped to detention pits. Under certain conditions it can be a potent source of pollution.

The clarified juice is sent to multiple-effect evaporators where it is concentrated from about 16 percent solids to about 65 percent solids. These units are operated on exhaust steam. The vapors from the last vessel are condensed, using a barometric-type condenser. The water from this condenser is used for the cane-washing operation. The other condensate from the evaporators is collected and sent to a storage tank from which it is drawn for boiler feed water, maceration water, and for use in the dilution of molasses in the pan-boiling operation. The resulting syrup from the evaporators goes to storage tanks for crystallization.

The syrup is crystallized in single-effect evaporators, called vacuum pans, to obtain crystalline sugar and a partially exhausted mother liquor, known as molasses.

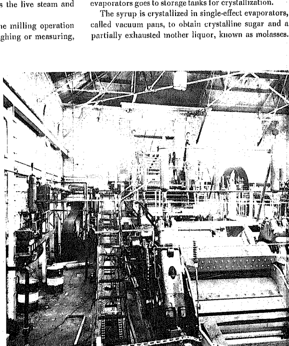


Figure 6.—Milling equipment for extracting juice from the sugar cane.

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This must be reboiled a total of three times to completely exhaust its available sucrose content.

The vacuum pans produce large volumes of vapors at subatmospheric pressure. These vapors are removed by condensation in barometric-type condensers. The warm condenser water from this operation is used for washing cane; is recycled to a cooling pond; or is discarded. The vacuum pans are operated on exhaust steam or vapors from the multiple-effect evaporator. The condensed steam furnishes water for process purposes or boiler feed use. This is normally collected in the condensate tank.

To assist in the exhaustion of the sucrose content of the molasses, particularly for the last boiling, the crystalline mass, plus its mother liquor, is sent to agitated storage tanks called crystallizers. Here the material is cooled while in motion which aids in the deposition of additional sucrose on the surface of the existing crystals. To accelerate the exhaustion of the material, these units are provided with cooling coils through which water is circulated. The warm water from this operation is ordinarily sent to waste along with the warm water from the condensers which include, in addition to those mentioned, the condenser used in conjunction with the rotary vacuum filter.

One of the last steps in the operation is the separation of the sugar crystals from their adherent mother liquor in centrifuges. (See Figure 7.) In the operation of these units, water may or may not be used for cooling clutches and brakes on the equipment. In the case of some sugar-molasses masses, or massecuites, limited amounts of water are required for washing the sugar in the centrifuge to remove the adherent molasses film. Water usage at this station is relatively minor and for that reason is not shown on the schematic flow diagram.

The flow diagram, Figure 8, has been prepared to show the flow of fresh and contaminated water in the process and to indicate the points at which pollutional materials may originate. The sources of pollution from cane sugar factory operations in relative order of importance are as follows: (1) Waste from the cane washing operation; (2) floor washings; (3) soda and acid wastes which result from the periodic cleaning of heat exchange equipment; (4) blowdown from the boilers; (5) excess condensate; and (6) condenser cooling water.

The relative volumes, character, and other properties of these various streams are discussed in the following section.

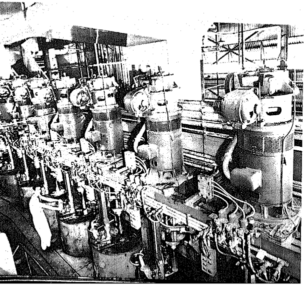

Figure 7.—Centrifuging sugar from crystalline mass produced by concentration of syrup and molasses.

A SIMPLIFIED FLOW DIAGRAM FOR RAW CANE SUGAR MANUFACTURE

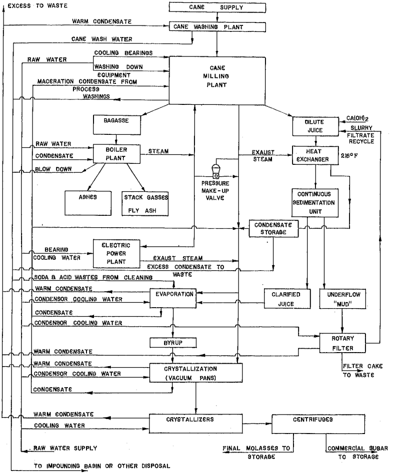

Figure 8.—A simplified flow diagram for raw cane sugar manufacture.

Volume and Character of Wastes

The volume and character of wastes arising from the operation of a raw sugar cane factory are quite variable depending upon local conditions. For example, where ground water is available or where adequate supplies of water from a local stream are convenient, factories frequently use water from these sources in their condensers and discharge it after use either to the stream from which it was drawn or to some other watercourse. Where water is not readily available, factories have recirculated it through cooling towers or spray ponds. In such cases the total water requirements for the plants are considerably reduced as is also the amount of water discharged from the operation.

Where possible, factories prefer to discharge the cake from their rotary vacuum filters in slurry form to a lagoon or other area because of convenience in handling. Usually at some later date, after the lagoon has drained and the material has been stabilized biologically, the partially dried material is removed for use as fertilizer. Where a suitable impounding area is not available, or if odors arising from such impounding areas are intolerable to nearby populations, factories need to remove the filter cake from their premises in the dry form. This material amounts to about 4 percent by weight of the cane ground.

The operation of cane laundries is common only in those areas which practice mechanical harvesting and loading of their sugar cane. Most sugar factories in the world do not find such laundries necessary because their cane is manually harvested and loaded. Where such laundries are operated, the amount of water employed and the extent to which these units are operated on a continuous basis depend largely on the availability of an impounding area into which the waste water can be discharged.

Factories can be operated on a very limited water supply if circumstances so require. There is a factory in the West Indies, for example, located in an area where rainfall is virtually nonexistent during the grinding period of some 5 months, and where there is no locally available ground or surface water of satisfactory quality. This factory is forced to operate on a total supply of approximately 1 million gallons of water which is available in cisterns at the time that the factory commences operation. In the course of processing sugar cane into sugar, the juice extracted from the cane averages about 80 percent by weight of the cane ground. When this juice is concentrated in multiple-effect evaporators, about 75 percent of its total weight is removed as water of condensation. That is, about 60 percent by weight of the cane ground may be recovered in the factory daily by condensation of the water evaporated from the cane juices. With proper care and operation, this water can be conserved and should be adequate to sustain the operation of the plant for protracted periods, assuming that the condensers are operated on a closed circuit by means of a cooling tower or cooling pond.

The figures which are cited in table 1 apply to conditions as they prevail in the Louisiana sugar industry at this time. They are by way of illustration only and are not necessarily applicable to all factories. They provide a basis on which the order of magnitude of the problem can be judged. Of the wastes listed, by far the most serious from the point of view of water pollution is that resulting from the cane laundering or washing operation. The nature of this waste is indicated by the data which follow.

TABLE 1.—*Volume and character of wastes from raw cane sugar production, Louisiana*

(2,400 tons cane daily capacity)

Kind of waste	Average flow rate (gpm)	5 day B.O.D. average (ppm)	Total daily B.O.D. load (lbs)
Cane wash water	1,000	680	8,157
Floor washings + boiler blowdown	100	378	453
Soda and acid wastes	10	NaOh, NaCl & HCl	----------
Excess condensate	50	10	6
Condenser water[1]	5,000	69	4,138
Totals	6,160	----------	12,754
Average per ton daily capacity	----------	----------	5.31

[1] Assumes once through operation.

Cane Wash Water

Cane washing operations require very large vol- umes of water. Plants use from a minimum of 500 to a maximum of 5,000 gallons of water per minute in his operation. The water carries in suspension large amounts of soil which have been removed from the cane, together with some fibrous material and a con- siderable amount of dissolved soluble organic and norganic materials. A figure of 2,900 parts per mil- ion total solids in cane wash water is normal for a plant operating under average conditions.

TABLE 2.—*Composition of cane wash water* (ppm)

otal solids	2900
uspended solids	2104
ettleable solids	1722

The water from the plant is screened to remove oarse, fibrous materials which are either sent back o the milling operation or removed in solid form. The creened waste water is then sent to a detention basin vhere additional coarse material (sand, etc.) settles ut. Much of the material in suspension is colloidal clay particles) which settles with difficulty. Because f the presence of large amounts of organic com- ounds, some of which act as protective colloids, this vater is difficult to clarify with ordinary flocculating gents. Usually about half of the total solids can be ettled out in the detention basins. The remainder f the material either remains in suspension or in solu- ion for subsequent destruction or removal in the im- ounding basins.

Since most of the material dissolved in the water is rganic and principally sugar, its B.O.D. value is uite high, ranging from a minimum of about 300 to a aximum of about 1,000 ppm. Variations result from e relative volumes of water used, the damage which e cane has suffered in the mechanical harvesting and ading operations, and similar practices. Water from is operation constitutes the most serious pollutional ad in raw cane sugar manufacture.

loor Washings and Boiler Blowdown

In the operation of the cane sugar factory there is very considerable volume of floor washings, par- cularly from the area around the milling plant. ther sections of the factory are also washed fre- uently and this waste material is added to the load. pills occur in the operation of plants from time to time and this material is normally washed down the sewer.

The boilers in the plant are usually operated on condensate but occasionally with some raw water. The general practice is to treat boiler water internally, using caustic soda, phosphates, an organic dispersion, and sulphites to scavenge traces of dissolved oxygen. Boiler blowdown varies from 5 to 10 percent of the volume of the feed. This material may be relatively high in contaminants though not so high in B.O.D.

The flow rates of these combined wastes are quite variable. The boiler blowdown is usually intermit- tent but of relatively constant total volume during con- tinued operation of the plant. Occasionally, when con- densate becomes contaminated with sugar through entrainment, boiler blowdown rates may be increased very substantially to eliminate the contaminated water, or the boilers may be completely emptied. On weekly shutdowns it is common practice to flush the boilers completely and at that time the total volume of water from the boiler station increases but the concentration of dissolved solids in the material diminishes.

Floor washings likewise vary widely in composition and in volume. The most serious loads occur on week- end shutdowns when the plant is given a very thorough cleaning. At that time, too, some equipment is emptied and the volume and concentration of washings may in- crease greatly. When spills occur there are likewise very wide fluctuations in the volume and concentration of washings. Usually an effort is made to dilute the washings to reduce concentration.

Soda and Acid Wastes

Periodically, sugar factories must clean their heat exchanger equipment because of fouling of heating surfaces by scale deposits. Conventionally, this is done at weekly intervals although some factories may run as long as 3 weeks between cleaning periods. The usual method of cleaning is first to rinse the equip- ment with water to remove adhering films of sugar solution, and then to boil the equipment with a caustic soda solution for about 6 hours. The caustic soda solu- tions are ordinarily reused from one cleaning to the next. After each cleaning the material is returned to a storage tank, reinforced with additional caustic soda, and the sludge from the bottom of the tank discharged to waste.

Following the cleaning with caustic soda and the draining of the solution, the equipment must be rinsed with water to remove the last traces of soda solution. This wash water goes to waste.

The second stage of cleaning involves boiling out the equipment with a dilute hydrochloric acid solution. These solutions are conventionally about 0.5 pH. The acid is usually inhibited with an organic inhibitor to reduce attack on the steel equipment. The boiling period is usually about 1 hour to 1½ hours. The spent acid solution is discharged from the equipment to waste. Following this operation the equipment is flushed with water to remove the last traces of acid residue. This material also goes to waste. Because of the difficulties which have been caused by the discharge of these soda and acid residues to public watercourses, the industry has long followed the practice of impounding them. They normally total about 100,000 gallons weekly during the operating period. All of this waste is usually discharged in a period of about 12 hours. The flow rate shown in table 1 was obtained by dividing the total weekly discharge to get the discharge rate in terms of gallons per minute. While this waste contains some organic material, it is principally inorganic in nature and creates a pollution problem because of its inorganic constituents rather than because of its B.O.D. content.

Excess Condensate

When a sugar factory is operating normally the volume of condensate produced is more than sufficient for the process requirements of the plant. These include boiler feed water, maceration water, water for the dilution of molasses which is to be recycled, and water for the washing of sugar during the centrifuging operation. Occasionally the excess condensate is used for floor-washing operations. Even with this utilization of condensate there is usually more of it produced than can be utilized. This excess is discharged as waste. When condensate is contaminated with sugar because of entrainment or carryover of solids with the vapor being condensed in evaporating equipment, it must be sent to waste since it is then unsuitable for boiler feed purposes. The total amount of condensate wasted is variable and is, therefore, not a uniform source of pollution load. Under ordinary conditions the condensate is virtually pure water with relatively little dissolved solids and practically no B.O.D. The dissolved material is principally organic in nature and frequently acidic in reaction. When contaminated, the B.O.D. content of this material may reach 300 to 400 ppm. Because the material is hot, its dissolved oxygen content is quite low which aggravates the pollution situation.

Factories normally run periodic checks on all condensate streams to determine whether contamination with sugar has occurred. This is done not only to check potential losses, but also as a matter of safety, since most of this water goes to boiler feed purposes.

Condenser Water

Wherever possible, factories operate on a "once through" system as regards condenser cooling water. Most factories are located adjacent to streams, lakes, or other water bodies from which an adequate supply of cooling water can be drawn. This water is pumped through barometric-type condensers where it picks up the latent heat of vaporization from the operation of evaporators and vacuum pans. The water leaving the condensers normally has a temperature of 110° to 130° F. It is relatively low in dissolved oxygen since it has been subjected to an absolute pressure of about 4 to 6 inches of mercury.

The volume of condenser water required for factory operation is dependent on the temperature difference between the inlet and outlet water and the weight of vapor to be condensed per unit time. The lower the water inlet temperature, with a relatively fixed exit temperature, the lower the volume of water required by the condensers. Where the temperature of the entering water is relatively high, as is the case with spray ponds or cooling towers, the amount of water which must be circulated in the system increases several fold. When water is recirculated it eventually becomes contaminated with organic materials because of entrainment. The water lost by evaporation in the cooling pond or tower is more than offset by the amount of vapors condensed. In such cases there is a continuous though relatively small overflow of water from the cooling system. This water normally goes to waste. In the data cited it has been assumed that the factory was operating on the "once through" system which is the more common arrangement under conditions such as exist in Louisiana. (See Figure 9.)

Condenser water in a properly operating factory will have a relatively low B.O.D. There should be little or no increase in B.O.D. through the system. Unfortunately, because of defective entrainment separators, operation of equipment at rates beyond design, and faulty operation, the entrainment of substantial amounts of sugar in condenser water is the rule rather than the exception in the industry as a whole. The values shown in table 1 are an average of several hundred determinations made over several years and cov-

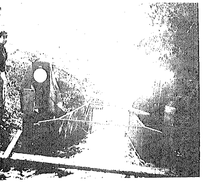

Figure 9.—Parshall flume and recorder for measuring flows, such data being needed in efficient water management at a cane-sugar factory.

ering some forty factories. B.O.D. values on condenser water ranged from as low as 2 ppm to as high as 600 ppm for those systems in which heavy entrainment losses were occurring. Eighty-one percent of all of the values determined were less than 100 ppm.

The B.O.D. load from condenser water is quite variable and is largely dependent on factory operating conditions. When the factory staff observe due precautions and equipment is well maintained, B.O.D. load from this source can be held to a negligible value. One of the difficulties, however, is that equipment which operates quite well with practically no entrainment losses may, through momentary negligence on the part of an operator, or some equipment failure, suddenly entrain very large amounts of sugar-bearing materials throwing sudden and heavy B.O.D. loads on the system. Continuous sampling and careful attention to the condition of equipment have made possible very substantial reductions in losses from this source.

In studies carried out in Louisiana over a period of several years, sugar losses of several tons per day have been found in factories where defective entrainment separators or poor operation have resulted in heavy contamination of condenser water supplies.

Condensers in the factory are used on three types of equipment. In the operation of rotary vacuum filters, a barometric-type condenser is interposed between the filtrate receivers and the vaccum pump. Because juices foam readily and leakage into the system is not uncommon, there are frequent occasions when considerable quantities of sugar are lost at this station because of an airlift effect which carries slugs of filtrate into the condenser even though it may be as much as 30 feet above the filtrate receivers.

In the operation of multiple-effect evaporators, the vapors from the last body in the system are discharged to a barometric-type condenser. Here entrainment may be substantial because of high velocities or defective entrainment separators. Vapors from the other bodies in the system are discharged into the heating sections of the successive bodies and are there condensed. If any entrainment occurs in these vessels it will show up as contamination in the condensate which is used in the process.

In the operation of the vacuum pans, individual condensers may be used on each vacuum pan or a single condenser may serve several. Here the dangers of entrainment are not usually so great as in the operation of evaporators. If operators do not fill equipment beyond the proper control level and are careful in operation there should be little or no danger of entrainment. Unfortunately, fluctuations in the water pressure available to the condensers, the steam pressure available to the heating section of the vacuum pan, and other operating variables sometimes cause slight fluctuations in the absolute pressure in the vacuum pans. Under such conditions it is possible to have "flashing" with momentary carry-over of sugar into the condensate, or entrainment. Losses can be substantial because of the high density of the material in the vessel, and its foaming tendency, especially during the preliminary stages of the crystallization operation.

Pollutional Effects

Wastes from sugar factories, following laundering operations, are principally in the form of floor washings which contain limited amounts of lubricating oils and greases. These are carried in the floor sweepings particularly from the milling operation. Suspended solids in the waste may be relatively high. These deposit and cause blockage of drainage ditches, filling of detention basins, plus delayed pollutional effects because of the slow decomposition of such settled materials on the bottom of ditches, streams, and lagoons. Waste materials from the heat exchanger and cleaning operations may be acid, alkaline, or neutral, depending upon conditions existing at the moment. Usually they are damaging because of their high salt content, plus their content of other dissolved inorganic salts which can be toxic to aquatic life.

Waste water leaving the factory may be relatively clear in appearance and offer no visible evidence of contamination. In many cases, when temperatures are not excessive, minnows may be able to live in such streams for protracted periods, provided the water is moving. Usually a period of 2 to 5 days is required before biological activity in the water becomes noticeable. Because of this time lapse no pollutional effects may be noted in the vicinity of the factory, but will appear miles downstream from the factory area. It is difficult at times for non-technical personnel to comprehend how the obvious pollutional effects at a point downstream from the plant are related to factory operations.

The noticeable effects include development of obnoxious odors because of anaerobic conditions usually prevalent in the contaminated stream, lake, or impounding basin. Contaminated waters will eventually turn black because of precipitation of iron by hydrogen sulfide as the stabilization proceeds. The odor problem in connection with stabilization lagoons is serious, particularly when such lagoons are near inhabited areas. Fish mortality in polluted streams occurs relatively quickly and well in advance of the development of odors and the blackened condition of the water.

In the impounding basins or lagoons as many as 150 days are required for complete stabilization of mixed factory wastes under conditions such as exist in Louisiana during the winter and spring months. In tropical areas where prevailing temperature conditions are more favorable, stabilization usually occurs in about 30 days. (See Figure 10.) The rate of B.O.D. reduction is very rapid at first. It is possible to arrive at a total B.O.D. value of about 40 to 60 ppm within 5 to 7 days after the material has been stored in a detention basin. Solids which settle out of cane wash water impounded without preliminary settling often adversely affect the stabilization of this material. This is due to a gradual release of B.O.D. from this material over a period of several months. It is highly desirable that any material which is sent to basins for stabilization be as free as possible from suspended material prior to lagooning.

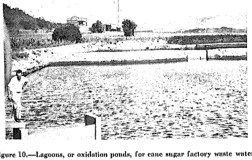

Figure 10.—Lagoons, or oxidation ponds, for cane sugar factory waste waters.

Remedial Measures

Careful attention to all phases of factory operation is the first essential in the control of the pollution load discharged from a factory. This involves a continuous check of all streams for sugar content and for their chemical oxygen demand. The use of B.O.D. determinations as a routine control measure is not feasible because of the delay required for this determination.

With careful attention to factory operations and continuous check on waste water streams, the B.O.D. load from condenser water and excess condensate can be minimized. The load due to floor washings, boiler blowdown, and particularly cane wash water, requires treatment or other measures for its reduction.

Cane Wash Water

The major pollutional load in factory operation is from the water leaving the cane-washing plant. The waste from this plant can be reduced in pollutional characteristics by improvements in harvesting and loading procedures. Such improvements should result in smaller quantities of extraneous materials in the cane deliveries. In addition, any improvements which reduce the amount of damage suffered by the cane in the mechanical harvesting operation will also reduce the pollutional load, since it will substantially reduce the amount of juice which exudes from the damaged cane.

Measures which have received study and experimentation in an effort to reduce the volume of wastes from cane washing have included partial settling and reuse of wash water. Particularly where factory location limits the volume of cane wash water waste which it can impound, it has been necessary to reduce the total amount of water used in the operation. By recovering the wash water, running it through a settling tank and removing the coarse, suspended material, this same water can be reused at least once in connection with the washing operation. It should be noted that the efficiency of the washing operation depends largely on the volume of water passed through the cane. The larger this volume the more effective normally is the removal of foreign materials, particularly soil. The procedure followed involves recovery of the wash water, partial settling, and reuse of this wash water in the initial washing stage. All fresh water used in the operation is added subsequent to the addition of the once-used material. Thus, the dirty water from the recycle operation serves to carry out some of the suspended matter and is itself removed by the fresh water entering the system.

Figure 11 illustrates the general procedure employed. With such a system it is possible to reduce the total volume of water used for the washing operation by about 50 percent. This does not, of course, reduce the B.O.D. load from this operation but, rather, produces a more concentrated waste material. Referring to the sketch it will be noted that the cane is loaded onto an apron-type conveyor which moves it from the cane storage area into the factory. Above the belt-type conveyor are located spray nozzles through which water can be sprayed on the slowly moving mat of cane. The location of sprays along the cane carrier is limited by the location of the revolving cane knives which are used to disintegrate the cane and reduce its volume. Since the cut cane cannot be washed because of excessive loss of sugar juices, any washing must precede the cane knives, with allowance of sufficient time to permit wash water to drain from the cane before it is knifed.

A centrifugal pump of adequate size and capacity picks up water from the warm condenser water canal and pumps it to the sprays above the cane carrier and nearest the cane knives. This is relatively clean water and serves to remove any soil or dirty water added by the preceding set of sprays. Because of the limited size of impounding lagoons the amount of water employed is usually of the order of 500 to 700 gpm. This water readily passes through the mat of cane and drains from the bottom of the conveyor into a steel or concrete trough. A strainer at the discharge end prevents coarse particles of leaves and cane from getting into the sand trap and causing difficulty. The entire discharge is passed to the sand trap where the coarse solids settle out and the partially clarified liquid overflows a circular weir and discharges into the sump of a vertical-type centrifugal pump. From here this water is pumped back to the first set of sprays where it serves to wet the cane coming into the system and to remove at least the major portion of the adherent soil and organic material. From time to time the sludge which accumulates in the bottom of the sand trap must be removed and pumped to a detention basin. The once-used water which is circulated through the second set of sprays passes through the mat of cane, removes the major portion of the fine material, and is in turn collected in a trough below the carrier and from there picked up and pumped to a settling basin. A chokeless-type centrifugal pump is used in this operation.

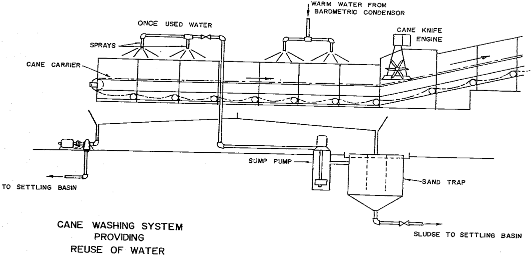

Figure 11.—Cane washing system providing reuse of water.

The use of a settling basin is essential to the successful operation of the cane-washing plant. The settleable solids form a relatively large percentage of the total solids in the waste water. If this water is discharged into a long and rather narrow pond, which can be approximately 30 feet wide and 150 feet long, there will be ample time for most of the settleable solids to deposit. The overflow from this pond can go to the detention basin for stabilization of the waste material. Usually the settling basin and the detention pond are arranged so that only one pump is needed. This is the pump which removes the material from the cane-washing plant to the settling basin. From that point, flow is by gravity. Corrosion and erosion problems in handling this material make it desirable to have as little mechanical equipment in this system as possible. Use of a long and narrow settling basin makes easy the removal of the settled solids with a conventional drag-line and bucket arrangement. Since the total amount of solids removed in the course of a 12-week grinding season may amount to several thousands tons, the importance of easy removal of this material will be self-evident. (See Figure 12.)

Pilot studies of the stabilization process at the Louisiana State University have indicated that most effective use can be made of the process involved by dividing the available space into three distinct areas. These areas can be separated by retaining walls. The division of the stabilization pond into three areas permits introduction of fresh wastes into the first area where it encounters waste which is already in process of active digestion by micro-organisms. Here the very substantial reduction of B.O.D. occurs at a relatively rapid rate. When the total B.O.D. has dropped to 100 or less, the rate of stabilization diminishes greatly. The initial rapid stabilization requires about 3 days so that the first area in the detention basin should provide for storage of 3-days' waste water production. (See Figure 13.) The second and third areas can divide the remaining space equally.

In the second area, the stabilization process continues at a reduced rate. The effluent from this area should be around 60 to 70 ppm B.O.D. This material passes to the third area from which it may be eventually discharged with a B.O.D. value of between 50 and 60 ppm.

Aeration during the initial stages speeds up the stabilization process. From incomplete pilot studies on the effects of aeration it appears that the rate of stabilization can be greatly increased. This, in turn, will permit either a smaller detention basin or use of larger amounts of wash water in the cane laundry.

When the cane wash water is not settled in advance of its arrival in the detention basins, the settleable solids deposit on the bottom of these basins and retard the rate of stabilization. This material includes considerable suspended organic materials which are entrapped by the settled solids. These organic materials decompose slowly and maintain a fairly high B.O.D. level in the ponds over long periods of time. With presettling, this situation can be avoided. By arranging the preliminary settling basin at a level above the

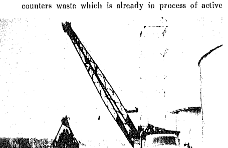

Figure 12.—Removal of solids from a preliminary settling basin for waste waters from a sugar factory.

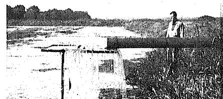

Figure 13.—Waste water from cane sugar factory entering first of a three-basin waste stabilization system.

detention basin, it is possible to drain the settled solids to a point where they can be removed and hauled away in conventional dump trucks.

Floor Washings and Boiler Blowdown

Because the concentration and volume of this class of waste material fluctuate so widely, and because these are concentrated wastes, factories have developed the practice of impounding them to permit stabilization prior to discharge to public waters. The total volume of such wastes accumulated during a normal 75-day grinding season is not excessive and, when evaporation and stabilization effects are considered, their impoundment should not present a serious problem. Such basins ordinarily include a separate section where entrapped oil and grease can be removed by skimming. (See Figure 14.) If the factory is also washing cane, tice which exists in many plants of allowing faucets to leak and hoses to discharge freely and continuously for long periods without serving any useful purpose, contributes to a substantial increase in the volume of this type of waste. By exercise of more care in washing operations, the total volume of material can be substantially reduced. The total B.O.D. load is not necessarily reduced in like proportion, but at least the storage problem can be alleviated by more care in the details of day-to-day operations. The use of steam in place of cold water for cleaning is more effective in removing the undesired sugar-bearing materials and permits a substantial reduction in the total volume of liquid discharged to waste. Greater care in checking condensate for contamination and observing concentrations of boiler feed water can bring about a substantial reduction in the amount of waste as a result of boiler blowdown.

Figure 14.—Oil and grease separated from factory wastes is skimmed off channels of waste disposal system.

it is common practice to discharge these wastes into the same basin or lagoon in which cane wash water is impounded.

The remarks concerning the handling of cane wash water apply equally to the treatment of the waste from floor washings and boiler blowdown. The total volume of this waste will not usually exceed 50 acre-feet, or 16.3 million gallons, in a 2,400-ton-capacity sugar factory operating over a period of 75 days.

The amount of floor washings and of boiler blowdown can be reduced by more careful attention to details of factory housekeeping and operation. The prac-

Soda and Acid Wastes

The production of soda and acid wastes is a characteristic of those areas which use chemical cleaning of heat exchange equipment. In some sugar-producing countries where chemical costs are quite high and labor is cheap, all evaporator heating surfaces are cleaned manually by scraping. This is a time-consuming operation and is rather hard on equipment, but does at least eliminate this source of waste materials.

Since the caustic soda used for cleaning is not completely reacted each time that the heating surfaces are cleaned it is practical and feasible to reuse the soda so-

lution for several cleanings. The usual practice is to determine the total active alkali in the solution following a cleaning period and then add sufficient new reagent to restore it to the desired strength prior to the next cleaning period. It is desirable, when this practice is followed, to drain from the caustic soda storage tank a portion of the settlings which deposit in the bottom as fairly concentrated material. It should be discharged through a separate impounding basin because of the adverse effect of the sodium ion on soils, and other difficulties, if released in the ordinary discharge channels.

The washing of the equipment following treatment with soda can also be a source of contamination and trouble. By proper attention to the installation of drain lines and provision of adequate time for removal of all caustic from the equipment prior to the washing with water, the concentration of caustic in such wash waters can be minimized.

Most plants use hydrochloric acid for the acid-cleaning operation. In some plants and areas, sulfamic acid has been substituted for hydrochloric because of the ease of handling the dry powder in comparison to the difficulties attendant on the use of a corrosive liquid. In either case the spent acid solutions must be discarded after cleaning because of the difficulties in storing dilute acid solutions. This material, too, must normally be discharged to a separate detention basin, usually the same basin in which the caustic wastes have been impounded. Since the total production is relatively small, its storage in a separate detention basin offers no serious problem. Where plants have no large bodies of water into which these materials can be discharged without causing difficulties, it is necessary to provide a small storage area which can be used from one season to the next. The total production of this material in the course of a normal season's operation will probably not exceed 10 acre-feet, or about 3.25 million gallons, in a well-operated factory.

Excess Condensate

Condensate disposal does not present a problem except in factories which are having difficulty because of leaking equipment or severe entrainment losses in evaporators. Proper care and supervision in the operation of heat exchange equipment can reduce contamination in condensate to a point where it can be discharged to watercourses without difficulty.

In areas where the supply of water at the factory is limited, the practice of discharging excess condensate to the cooling water system is followed. The heat load, because of the temperature of this water, is the only problem which develops with this practice.

Condensate should not present a waste disposal problem. If it does, the solution lies, not in reducing the amount of condensate, but in reducing the sources of contamination which will not only eliminate the pollution problem but also result in substantial savings to the factory.

Condenser Cooling Water

Factories use large volumes of cooling water, particularly where cooling towers or spray ponds are not employed to enable operation with a closed system. This water is used for service in barometric condensers. It is also used in the cooling of bearings on the mills, bearings on rotating equipment, and for many other similar cooling purposes. In virtually every use to which the water is subjected there is a possibility for contamination with sugar-containing material. For that reason it is important that that water be checked at regular intervals for contamination. Where contamination is due to leakage this situation should be corrected since it can represent a substantial loss of sugar. Other sources of pollution are principally the result of entrainment in connection with the operation of evaporators and vacuum pans.

In the course of several years' investigation of the problem it was found that entrainment to a greater or lesser degree was present in practically every operating unit studied. Sugar liquors tend to foam because of traces of surface active agents present in the cane juice. This tendency, plus operation of equipment at rates exceeding initial design, is a frequent cause for entrainment. The design of separators used for entrainment removal is frequently found deficient. The problem is further complicated by the failure on the part of operating personnel to insure that such separating equipment as is available is kept in first-class condition.

The solution of the problem involves, first, careful sampling and testing of waters from each condenser at regular intervals to determine whether entrainment is present or not. Second, it is essential that all separators be given a thorough examination at least weekly to insure that return lines are open and that the separator itself is in good mechanical condition. Where careful attention to operating conditions and the mechanical condition of the equipment has not solved the problem, separators of a more efficient type

should be installed. Two general types are available. The centrifugal-type separator can be purchased as a custom-built job or can be fabricated locally. In this unit the vapors leaving the evaporator or vacuum pan are given a twist to impart centrifugal motion which results in the entrained liquor being thrown to the outer walls of the vessel and thus removed from the stream of escaping gases. This type of unit is very effective but does require attention to the return lines to see that they do not become fouled or closed because of scale or rust from the vessel itself. The use of wire-mesh-type demisters or separators has also proved extremely satisfactory, particularly in connection with evaporator operations. These units should be installed at a distance of at least six to eight feet above the upper tube sheets of evaporator bodies. They require relatively little attention or maintenance. They must be inspected periodically for the deposition of incrustations on the lower surface. Washing them periodically with a hose will keep the unit in good operating condition.

When the cooling water used in condensers is recycled through the system, it frequently becomes contaminated with the products of decomposition of the sugar-bearing materials. In such cases, the detection of traces of sugar is difficult, particularly by the conventional alpha-naphthol test. It has been found that a more satisfactory indication of contamination in such cases is obtained by using the oxygen consumed by permanganate tests (O.C.). In such cases samples of the water entering the system are analyzed and compared with samples of water leaving the condenser. It has frequently been noted that, while the alpha-naphthol test was inconclusive, a very definite increase in O.C. could be detected and was indicative of entrainment losses. Losses of several tons of sugar per day have been found and eliminated by this procedure.

Sampling and Analytical Procedures

Contaminated water from sugar factory operation can be greatly reduced in quantity by better housekeeping and a more careful check on processing operations. Reduction in losses due to mechanical, chemical, or other reasons can be achieved on the basis of a carefully conceived and executed program for sampling and analyzing all waste streams from the factory. Sampling on a continuous basis is to be recommended and preferred over intermittent sampling. Equipment which is leaking, or in which entrainment is occurring, frequently performs erratically and catch samples may fail to show losses which occur from time to time. Continuous sampling is much more satisfactory and reliable for this reason.

The standard procedure for checking the samples for traces of sugar is the use of an alcoholic solution of alpha-naphthol. It has been noted previously that this method is not reliable, particularly when the water is being recycled and has become contaminated with decomposition products. In such cases the oxygen consumed from permanganate test (O.C.) is to be preferred.

When information on a more quantitative basis is desired, the use of ammonium-phosphomolybdate is recommended. A description of this procedure can be found in most handbooks on sugar analysis. A blue color is developed in the solution which is contaminated with sugar. The intensity of the color depends upon the concentration of the sugar. By preparing color standards by using refined sugar, it is possible to determine approximately the sugar content of contaminated waters. The color development is fleeting and new standards must be prepared at frequent intervals.

The maintenance of a factory log or record of all tests is extremely important for the benefit of operating personnel and as a means of checking on the development of difficulties from time to time.

Summary and Conclusions

There are several sources of waste waters leaving cane sugar factories. Of these sources, only two are major: cane wash water, and floor washings. Waste water from cane wash plants is very high in B.O.D. and is produced in large quantities. Special impounding basins or treatment methods are required for stabilization of this type of waste.

Floor washings, boiler blowdown and soda and acid wastes are small in volume but fairly high in B.O.D. This material is usually handled by detention basins.

Water used in condensers may become contaminated because of defective equipment. In such cases, because of the volume of water involved, correction of the defective equipment is indicated and the inauguration of a very careful sampling and testing procedure is needed to insure that there is no repetition of such failures.

The savings which a factory can realize through careful attention to its waste streams will more than offset the cost of such additional work. This has been proved many times by actual plant experience. The measures outlined constitute practical, economical procedures for the cane sugar industry to reduce wastes and solve pollution problems.

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